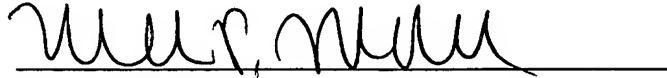## REMARKS

It is respectfully requested that the amendments to the claims be entered and the application be examined on the merits. It is believed that no new matter has been added by these Amendments. With these Amendments, claims 1, 5-8, 10-14, 17-22, 26-33, 35-41, 43-45, 49-52, and 54 remain pending in the case. Claims 2-4, 9, 15, 16, 23-25, 34, 42, 46-48 and 55-58 as filed have been canceled without prejudice to prosecuting the subject matter of these claims in an application to be filed at a later time.

Remarks regarding prior prosecution

In the parent of this application, the only remaining rejections were based on 35 USC §102 and §103. The art cited was Davidonis et al (US 4672035) and Umbeck (US 5159135). Applicants believe that the prior §102 rejection based on Davidonis (provided that such rejection is maintained herein) as it relates to the use of cobalt as an ethylene inhibitor is overcome by the amendment to claim 14 provided herein. Regarding the prior §103 rejection based on the combination of Davidonis and Umbeck, applicants respectfully submit the attached pages 162-168 from the textbook <u>Introduction to Biophysical Plant Physiology</u> from Chapter 6 entitled, Light. In the prior rejections, the Patent Office has asserted that "even though 0.5 μEinsteins m^{-2} sec^{-1} is not the exact same as 0 μEinsteins m^{-2} sec^{-1}, the difference is negligible barring lack of evidence to the contrary" (see Paper number 10, page 3 from US Serial No. 09/466629), the evidence submitted here illustrates both the importance of light as a trigger to many plant activities as well as the quantifiable amount of energy that can be determined from any quantity of light. It should be beyond question that by introducing an amount of energy corresponding to 0.5 μEinsteins m^{-2} sec^{-1} of light to plant tissue is likely to impact such tissue differently that a lack of such energy provided at 0 μEinsteins m^{-2} sec^{-1}. Thus, it is incorrect to equate "low" levels of light with "dark" lighting conditions of 0 μEinsteins m^{-2} sec^{-1}.

Should any questions arise, or if Applicants or Applicants' attorney can facilitate in the examination of this case, please contact the undersigned attorney.

Respectfully submitted

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INTRODUCTION TO
BIOPHYSICAL
PLANT PHYSIOLOGY

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CHAPTER FOUR

LIGHT

As we all know, the sun helps maintain temperatures on the earth suitable for plants and animals. The sun is also the ultimate source of the energy needed to sustain life. Through a series of nuclear reactions taking place within the sun, nuclear mass is converted into energy in accordance with Einstein's famous relation, $E = mc^2$. Such conversion of mass to energy enables the sun to maintain an extremely high temperature and to radiate a great amount of energy into space. Some of this radiant energy is incident on the earth, of which only a fraction is absorbed by plants. This absorption initiates the energy flow through the biosphere (plants and animals and that portion of the earth they inhabit). The first step in the utilization of sunlight is the conversion of its radiant energy into various forms of chemical energy by the primary processes of photosynthesis. Such chemical energy may then be stored in the plants, mainly in the form of carbohydrates. Plants act as the direct source of energy for herbivorous animals and indirectly for carnivores which eat the herbivorous animals. Omnivorous animals such as man feed upon plants as well as other animals—again, the ultimate source of energy being the solar radiation trapped by photosynthesis. Without a continuous energy input such as occurs from the sun, plants and animals would drift toward equilibrium and consequent cessation of life.

Sunlight also regulates certain activities of many plants and animals by acting as a trigger. The energy to carry out such activities is supplied by metabolic reactions, not directly by the light itself. Examples where light acts as a trigger are vision, phototaxis, phototropism, and phytochrome regulation of certain plant processes.

In this chapter we will be primarily concerned with the physical nature of light and the mechanism of light absorption by molecules. We will discuss how molecular states so excited can promote endergonic (energy-requiring) reactions or be dissipated by other types of de-excitation processes. In

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Chapter 5 we will consider Chapter 6 the bioenergetics of in organelles. In Chapter 7 v by radiation is dissipated by

To help introduce the to historical developments in th McElroy, or Halliday and R Newton showed that a prism colors, suggesting that such components. Soon thereafter light through space could be t attributed interference prope a wave theory of light was r Foucault demonstrated that such as water than in a rar of the wave theory. In 1887 l of a metal could cause the rel that light above a certain w no matter what the total en contradictory to the then ac departure from wave theory particle-like, i.e., light was d of specific energy. In 1905 Hertz as a special example the absorption of a light qu electron in the metal could release of that electron—if th quanta were not energetic wave-particle duality of lig consistent manner through though this text does not requ knowledge of this field is real of light.) Both wave and p complete description of radi chapter.

Wavelength and n rgy

Light is often defined as rad such a definition may be str

Chapter 5 we will consider the primary events of photosynthesis and in Chapter 6 the bioenergetics of energy conversion, especially that taking place in organelles. In Chapter 7 we will demonstrate how the net energy input by radiation is dissipated by a leaf.

To help introduce the topic of light, we shall briefly review certain historical developments in the understanding of its nature (see Seliger and McElroy, or Halliday and Resnick for further historical details). In 1666 Newton showed that a prism could disperse white light into many different colors, suggesting that such radiation was a mixture of a large number of components. Soon thereafter, Huygens proposed that the propagation of light through space could be by wave motion, while in the early 1800s Young attributed interference properties to the wave character of light. However, a wave theory of light was not generally accepted until about 1850 when Foucault demonstrated that light travels more slowly in a dense medium such as water than in a rare medium such as air, one of the predictions of the wave theory. In 1887 Hertz discovered that light striking the surface of a metal could cause the release of electrons from the solid. He also found that light above a certain wavelength could not eject any electrons at all, no matter what the total energy in the beam. This important result was contradictory to the then accepted wave theory of light. In an important departure from wave theory, Planck proposed in 1901 that radiation was particle-like, i.e., light was describable as discrete packets, or quanta, each of specific energy. In 1905 Einstein explained the photoelectric effect of Hertz as a special example of the particle nature of light, indicating that the absorption of a light quantum of sufficiently short wavelength by an electron in the metal could supply enough energy to cause the ejection or release of that electron—if the wavelengths were longer, then the individual quanta were not energetic enough to eject any electrons. The intriguing wave-particle duality of light has subsequently become described in a consistent manner through the development of quantum mechanics. (Although this text does not require a background in quantum mechanics, some knowledge of this field is really essential for a comprehensive understanding of light.) Both wave and particle attributes of light are necessary for a complete description of radiation, and we will consider both aspects in this chapter.

Wav l ngth and energy

Light is often defined as radiation perceived by the human eye. Although such a definition may be strictly correct, the word *light* is frequently used

to refer to a larger class of electromagnetic waves. In this section we will discuss the range of electromagnetic radiation that is important in plant and animal physiology, including the subdivisions into various wavelength intervals. The wavelength of light will be related to its energy. After noting the units for radiant flux and illumination, we will briefly consider some of the characteristics of solar radiation reaching the earth.

Light waves. Our concern here is with the regular and repetitive changes in the intensity of the minute electric and magnetic fields which indicate the passage of a light wave (cf. Fig. 4.1). Light can travel in a solid (glass), in a liquid (water), in a gas (air), and even in a vacuum (between the sun and the earth's atmosphere). One way to characterize light is by its wavelength—the separation in space between successive points of the same phase, such as between two successive peaks of a wave train (Fig. 4.1). A wavelength is the distance per *cycle* of the wave. One unit for wavelengths of light is the Ångstrom (Å), which equals 10^{-8} cm or 10^{-10} m (App. III). Another is the millimicron. However, the presently preferred unit for wavelengths of

Table 4.1
Definiti ns and characteris
The ranges of wavelengths le.
somewhat arbitrary and vary
the table refer to the particul
wavelength interval. Wavelen

Color	Approximate wavelength range (nm)	Re
Ultraviolet	below 400	
Violet	400–425	
Blue	425–490	
Green	490–560	
Yellow	560–585	
Orange	585–640	
Red	640–740	
Infrared	above 740	

light is the nanometer (nm
be used in this text (1 nm

The wavelength regions
the visible, and the infrare
are referred to as ultraviole
violet, in the sense of havin
from approximately 400 n
such as blue, green, or re
subjective color experien
wavelengths longer than t
to approximately 40 μm.

Besides wavelength, we
of oscillation, ν, and by a
v. These three quantities

$$\lambda\nu = v$$

where λ is the wavelength.
is a constant, generally
299,792 $\pm$ 1 km/sec, or
Monk for measurements
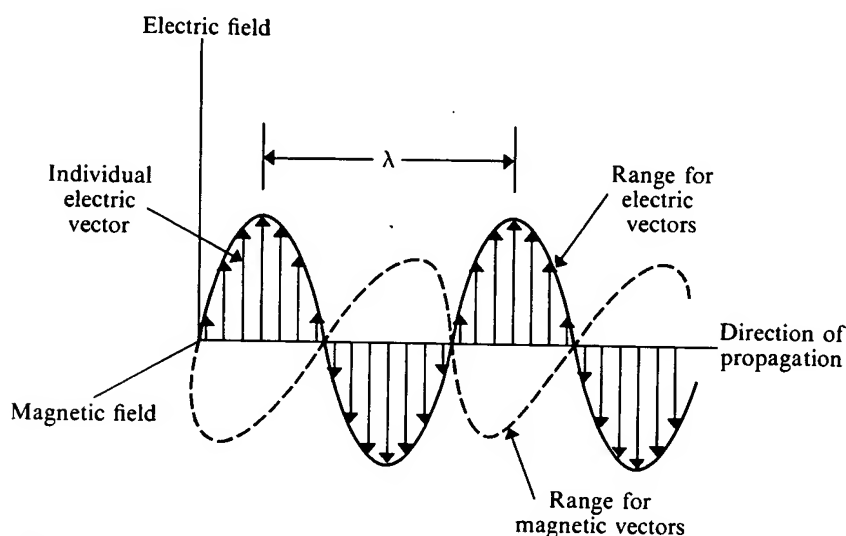medium other than a vac
having a wavelength of 5

Figure 4.1

Light can be represented by an electromagnetic wave corresponding to oscillations of the local electric and magnetic fields. The oscillating electric vectors at a particular instant in time are indicated by arrows in the diagram. A moment later, the entire pattern of electric and magnetic fields will shift in the direction of propagation of the wave. A wavelength (λ) is the distance between two successive points of the same phase along the wave.

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10^{10} m (App. III). Another is
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Tabl 4.1
Definiti ns and characteristics of the various wavelength regions of light.
The ranges of wavelengths leading to the sensation of a particular color are
somewhat arbitrary and vary with individuals. Both frequencies and energies in
the table refer to the particular wavelength indicated in column 3 for each
wavelength interval. Wavelength magnitudes are those in a vacuum.

Color	Approximate wavelength range (nm)	Representative wavelength (nm)	Frequency (cycles/sec) (Hertz)	Energy (ev per photon)	Energy (kcal/"mole" of photons)
Ultraviolet	below 400	254	11.80×10^{14}	4.88	112.5
Violet	400–425	410	7.31×10^{14}	3.02	69.7
Blue	425–490	460	6.52×10^{14}	2.70	62.2
Green	490–560	520	5.77×10^{14}	2.39	55.0
Yellow	560–585	580	5.17×10^{14}	2.14	49.3
Orange	585–640	620	4.84×10^{14}	2.00	46.2
Red	640–740	680	4.41×10^{14}	1.82	42.1
Infrared	above 740	1400	2.14×10^{14}	0.88	20.4

Range for
electric
vectors

Direction of
propagation

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etic vectors

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The oscillating electric
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agnetic fields will shift in
gth (λ) is the distance
ng the wave.

light is the nanometer (nm)—like the millimicron, it is 10^{-9} m—and it will
be used in this text (1 nm $= 10$ Å).

The wavelength regions of major interest in biology are the ultraviolet,
the visible, and the infrared (Table 4.1). Wavelengths below about 400 nm
are referred to as ultraviolet (UV)—meaning on the other side of, or beyond
violet, in the sense of having a shorter wavelength. The visible region extends
from approximately 400 nm to 740 nm and is subdivided into various bands
such as blue, green, or red (Table 4.1). These divisions are based on the
subjective color experienced by humans. The infrared (IR) region has
wavelengths longer than those of the red end of the visible spectrum, up
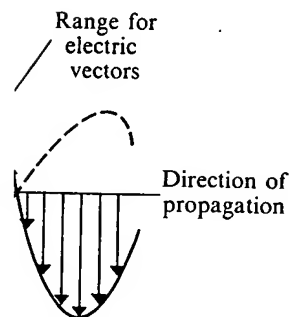to approximately 40 μm.

Besides wavelength, we can also characterize a light wave by its frequency
of oscillation, ν, and by a velocity of propagation that has the magnitude
v. These three quantities are related as follows:

$$\lambda\nu = v \tag{4.1}$$

where λ is the wavelength. For all wavelengths the speed of light in a vacuum
is a constant, generally designated as c, which experimentally equals
$299,792 \pm 1$ km/sec, or 3.00×10^8 m/sec (see Halliday and Resnick, or
Monk for measurements of the speed of light). Light passing through a
medium other than a vacuum has a speed less than c. For example, light
having a wavelength of 589 nm in a vacuum is decreased in speed 0.03%

by air, 25% by water, and 40% by dense flint glass. The wavelength undergoes a decrease in magnitude equal to the decrease in the speed of light in these various media, while the unchanging property of a wave propagating through different media is its frequency. Note that ν is the frequency of the oscillations of the local electric and magnetic fields illustrated in Figure 4.1.

For light, $\lambda_{vacuum}\nu$ equals v_{vacuum} by Equation 4.1, where v_{vacuum} is the constant c. Therefore, if we know the wavelength in a vacuum, we can calculate the frequency. In fact, the wavelengths given for light generally refer to values in a vacuum, as is the case for columns 2 and 3 in Table 4.1 (λs in air differ only slightly from the magnitudes listed). As a specific example, let us select a wavelength in the blue region of the spectrum, e.g., 460 nm. By Equation 4.1, the corresponding frequency equals c/λ_{vacuum}, or $(3.00 \times 10^8 \text{ m/sec})/(460 \times 10^{-9} \text{ m/cycle})$, which is 6.52×10^{14} cycles/sec for such blue light. Since ν does not change from medium to medium, it is often desirable to describe light by its frequency, as has been done in column 4 of Table 4.1.*

Energy of light. In addition to having wave characteristics, light can also exhibit particle-like properties, as in the case of the photoelectric effect mentioned above. Thus, light can act as if it were divided (or quantized) into discrete units, which we call photons. The light energy (E_λ) carried by a photon is

$$E_\lambda = h\nu = hc/\lambda_{vacuum} \tag{4.2}$$

where h is a fundamental physical quantity called *Planck's constant*. By Equation 4.2, a photon of light has an energy directly proportional to its frequency, and inversely proportional to its wavelength in a vacuum. For most applications in this book, we will describe light by its wavelength λ. By way of emphasizing that the light energy of a photon depends on its wavelength, we have used the symbol E_λ in Equation 4.2. Finally, a *quantum* (plural:quanta) refers to the light energy carried by a photon, i.e., $h\nu$ represents a quantum of electromagnetic energy. The terms "photons" and "quanta" are sometimes used interchangeably, a usage that is generally clear but strictly speaking not correct.

The introduction of the constant h by Planck in the early 1900s represented a great departure from the accepted wave theory of light. It substan-

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*The wavelength of light is generally expressed in nm, not nm/cycle, and ν is considered to have units of $\sec^{-1}$ (not cycles/sec) for purposes of calculation.

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decrease in the speed of light
property of a wave propagating
Note that ν is the frequency
magnetic fields illustrated in

ation 4.1, where ν_{vacuum} is the
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frequency equals c/λ_{vacuum}, or
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a usage that is generally clear

nck in the early 1900s repre-
ive theory of light. It substan-

in nm, not nm/cycle, and ν is
for purposes of calculation.

tially modified the classical equations describing radiation and provided a rational basis for determining the energy of a given number of photons. Since frequency has the units of reciprocal time, Equation 4.2 indicates that Planck's constant dimensionally is energy × time, the appropriate unit depending on the particular application. For instance, h is equal to 6.626×10^{-27} erg-sec, 0.4136×10^{-14} ev-sec, or 1.584×10^{-37} kcal-sec (App. II).

For many purposes, we may find it convenient to express the energies of individual photons in electron volts (ev). Ionization potentials and the spacings between energy levels in atoms and molecules are often so expressed. Blue light of 460 nm has a frequency of 6.52×10^{14} cycles/sec (Table 4.1). From Equation 4.2, a quantum of such light has an energy $h\nu$ of $(0.4136 \times 10^{-14}$ ev-sec$)(6.52 \times 10^{14}$/sec$)$, or 2.70 ev. Using Equation 4.2 and the appropriate numerical value of hc, we can also calculate energies in electron volts from the wavelengths of light. Since hc is equal to 1240 ev-nm (App. III), blue light of 460 nm—strictly speaking, this is the wavelength in a vacuum—has an energy of (1240 ev-nm)/(460 nm), or 2.70 ev. Table 4.1, column 5, gives the energy in ev/photon at various wavelengths in the ultraviolet, visible, and infrared.

The customary energy unit for chemical reactions is the kcal/mole, and it is often advantageous to express light energy in a comparable way. The unit analogous to moles but used for radiation is the *Einstein*, which has Avogadro's number (6.023×10^{23}), N, of photons. Although not strictly correct, a "mole" of photons is often used to refer to 6.023×10^{23} photons.* Using Equation 4.2 and the appropriate numerical value of h, we can calculate that the energy of an Einstein (mole) of photons of blue light of wavelength 460 nm is $Nh\nu$, or $(6.023 \times 10^{23}$/mole$)$ $(1.584 \times 10^{-37}$ kcal-sec$)$ $(6.52 \times 10^{14}$/sec$)$, which equals 62.2 kcal/mole. Likewise, since Nhc equals 28,600 kcal-nm/mole (App. III), we can also calculate the energy of 460 nm photons using their vacuum wavelength, which gives (28,600 kcal-nm/mole)/(460 nm), or 62.2 kcal/mole. The energies of various wavelengths of light are presented in kcal/mole of photons in the last column of Table 4.1.

We can see that quanta of visible light represent relatively large amounts of energy. The hydrolysis of ATP, the main currency for chemical energy

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*The term *mole* refers of course to a mass equal to the molecular weight in grams, a unit which contains N molecules (App. IV). Since light has no mass, mole is not really an appropriate expression, although such usage is widespread and the actual meaning is clear.

in biology, yields about 10 to 14 kcal/mole under physiological conditions (see Ch. 6), while blue light has about five times as much energy/mole of photons. Quanta of ultraviolet light represent even higher energies than those of visible light, e.g., 254 nm photons have 113 kcal of radiant energy/mole (Table 4.1). This is greater than the carbon-carbon bond energy of 83 kcal/mole or the oxygen-hydrogen bond energy of 111 kcal/mole. The high quantum energy of UV radiation underlies its mutagenic and bactericidal action, since it is energetic enough to cause disruption of certain covalent bonds.

The photoelectric effect, where light leads to the ejection of electrons from the surface of a metal, clearly illustrates the distinction between light energy and the energy of its quanta. The amount of energy required to remove electrons from the surface of metallic sodium was found by R. A. Millikan to be 1.82 ev/electron, or 41.9 kcal/mole of electrons, which corresponds to light of wavelength 683 nm (see Halliday and Resnick).* Quanta of light energy representing wavelengths of 683 nm or less thus can lead to a photoelectric effect for sodium. However, no matter how much light energy for wavelengths beyond 683 nm is absorbed, electrons are not ejected from the surface. Hence, the energy of quanta specifies the quality of the radiation, while the total light energy is a measure of its quantity without indicating how many photons are actually involved.

Absorption of radiation by an atom or molecule leads to a more energetic state of the absorbing species. Such energetic states can also be produced by collisions resulting from the random thermal motion of the molecules. The higher the temperature, the greater is the average kinetic energy of the atoms and molecules, and the greater is the probability of achieving a relatively energetic state by collision. The number of molecules having a particular kinetic energy can often be approximated by the Boltzmann energy distribution (see p. 121). By Equation 3.21 ($n(E) = n_{total} e^{-E/kT}$), the fraction of atoms or molecules having a kinetic energy of molecular Brownian motion of E or greater at thermal equilibrium equals the Boltzmann factor, $e^{-E/kT}$, where k is the Boltzmann constant (8.617×10^{-5} ev/molecule-°K, App. II). Therefore, the number of molecules with kinetic energy in excess of E at a given temperature exponentially decreases with increasing values of E. Energies of molecules are generally of the order of magnitude of kT, which equals (8.617×10^{-5} ev/molecule-°K)(298°K), or 0.026 ev/molecule, at a temperature of 25° (298°K). For instance, the average kinetic

energy of translation for mol at 25°.

Next, we will use the E fraction of the molecules tha kinetic energy, namely, 0.1 mann factor, $e^{-E/kT}$, equals 0.026 ev at 25°). Therefore, have a kinetic energy of at On the other hand, the ab: excited state of the same e hc/λ_{vacuum} (Eq. 4.2), where to a photon with a waveleng is in the IR. Absorption o of certain reactions because more reactive. Turning the a at what temperature would cules have a kinetic energy then be e^{-1}, where E is 0.1 molecule)/(8.617×10^{-5} ev/ words, a very high temper energetic states by thermal by absorbing infrared radi:

As an example of an exc us consider a kinetic energ $e^{-(2.70)/(0.026)}$, or only 4×10 cule gaining 2.70 ev or mc extraordinarily small. Fron 460 nm. The absorption of otherwise would simply nc and animals. Absorption c promotes the attainment o: a key feature in the under

It will no doubt be notic sions: (1) molecule, mass o (2) mole, molecular weigh second set is simply Avogad expression in the first set. venience, and either one i paragraphs could equally w of ev/molecule (1 ev/mole we must replace kT by RT

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* For his careful work on the photoelectric effect, Millikan was awarded the Nobel prize in physics in 1923.